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AUTHOR Griffin, Jane; Tubb, Gary W.
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ABSTRACT

A project to determine if a causal relationship exists between attitude and achievement in understanding metric concepts is described. The subjects of the project were inservice teachers. The answer to two questions were sought: Does a positive significant correlation exist between initial attitude and achievement? Does a significant difference exist between the correlation coefficients for initial attitude and final understanding and initial understanding and final attitude scores? In other words, does a causal relationship exist between initial attitude and knowledge growth? Prior to metric instruction, all participants completed attitude scales and metric knowledge tests. The same tests were administered at the end of 15 hours of instruction by metric specialists. Although the correlations tended to support the hypothesis that initial attitude affects final understanding more than initial understanding affects final attitude, a clear conclusion was not reached. It was, however, determined that the subjects improved in both attitude and understanding and are more adequately prepared to teach metric measurement. The methodology of making a cross-lagged analysis is explained and the accuracy of results discussed. (JD)

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TITLE: Cross-Lagged Analysis of Teacher Attitude and Achievement in Inservice Metric Training.

PRESENTERS: Jane Griffin, High School Mathematics Teacher, Atlanta, Louisiana.
Gary W. Tubb, Northwestern State University, Natchitoches, Louisiana.

ABSTRACT

Within the last decade, the United States has moved toward total metrication of the system of measurement which has become a mandatory part of the public school curriculum. To avoid the same pitfalls which were experienced by the "modern mathematics" movement, teacher attitudes and understanding must be favorable to the teaching of metrics. Many believe a causal relationship exists between understanding and attitudes. Inservice training in metrics was available to teachers in four Louisiana parishes. Pre and posttests were administered to evaluate the success of the program in improving attitudes toward and understanding of the metric system. Cross-lagged panel analysis was used to determine if a causal relationship exists. There are twenty-one references.

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Cross-Lagged Analysis of Teacher Attitude and Achievement in Inservice Metric Training

In 1866, the United States Congress legalized the use of the metric system of measurement for those citizens who desired to use it. (Moore, 1974:12) The metric system was not new at that time. During the French Revolution the meter had been standarized as being one ten-millionth of the circumference of the earth from the North Pole to the equator. Use of the metric system later spread through the European continent, British Isles excluded, and was labeled the French System of Measurement. (Moore, 1974:11)

In August, 1972, the Metric Conversion Act passed unanimously in the United States Senate, but failed to pass the House of Representatives because of concern for the cost of national conversion. (Hughes, 1975:7) The bill finally passed both houses in 1975 and was signed by the President on December 23, 1975. (Anderson, 1976:9) The final passing was forced by several factors, one of which was the decision by England to change to the metric system in 1965. British Metrication left the United States as the last major power not using the system. Other major powers did not want to have to convert customary units to metric in order to trade with the United States. Many of the industrial powers in the United States had already decided to make the change. Among these were Ford Motor Company, General Motors, International

Harvester, and International Business Machines. (Deming, 1974:16) Vollmer (1975:35) stated, in May, that the international economic pressures would make the adoption of the metric system in the United States a reality. One conjecture is that the United States would have gone metric even if the Congress had not passed the law because of the influence of industry and international pressures.

The U. S. Metric Study recommended that a ten year period be assigned for the country to become predominantly metric. Although Congress set no time lines as a concession to organized labor, the metric system is quickly becoming a household word. (Anderson, 1976:5) The American people will have to learn the metric system, or parts of it, to be able to carry out their responsibilities.

The U. S. Metric Study encouraged two major steps to the coming metrication of the United States. The first of these is the education of the school children. "Every school child should have the opportunity to become as conversant with the metric system as he is with our present system." (DeSimone, 1971:xvi) The majority of Americans are not yet acquainted with the metric system, but those who are informed tend to favor the changeover. Since those who are informed have a positive attitude toward the changeover, education of the public to help them cope with the problems associated with a metric America is of utmost importance.

The problems involved with teaching the metric system are many. One of the problems is the over-riding negative

opinion concerning the International Metric System. Another problem to be reckoned with in the first stages is education of the teachers who will be teaching the system. Teachers will need to learn with their students until they are comfortable living and thinking metric. (Doherty, 1976:474) A great deal has been written on the importance of adequate knowledge and positive attitudes toward the lesson to be taught, as well as the proper methodology for presentation. King and Whitman (1973:258) said that teachers should be taught using the best method since they usually teach the way they are taught. The "Going Metric" project, funded by ESEA, Title IV-C, was designed to provide teachers in the Louisiana parishes of Bienville, Jackson, Sabine, and Winn with the knowledge and methodology necessary to effectively integrate metric instruction into the regular classroom.

Teachers were given metric instruction by metric specialists using the "think metric" approach. (See Appendix A) Pre and posttests were administered to evaluate the success of the program in both attitude change and knowledge growth. Many believe a causal relationship exists between understanding and attitude. Aiken (1970:551-596, 1976:293:311) provided the best summary of research on attitudes toward mathematics. The cross-lagged analysis technique was employed to infer the direction of the causal relationship, if, in fact, one exists, between attitude and achievement in understanding metric concepts. The questions to be answered are: (1) Does a positive significant correlation exist between initial attitude and achievement

in metric understanding? (2) Does a significant difference exist between the correlation coefficients for initial attitude and final understanding and initial understanding and final attitude scores? In other words, does a causal relationship exist between initial attitude and knowledge growth?

METHOD

Subjects

The data on which the analyses were based were provided by the "Going Metric" project in the Louisiana parishes of Bienville, Jackson, Sabine, and Winn. A total of 1209 persons participated in the project, 970 of which were public school teachers. All teachers and administrators were required to participate in the project by the respective parish officials. The fifteen hours of instruction, divided into five sessions, counted as inservice training time which is required by the state of Louisiana for all public school teachers each year.

Although the original proposal called for differentiated classes of measurement and nonmeasurement teachers, the classes were not differentiated. Of the 970 teachers involved, 267 subjects were identified on all four measurement instruments. Prior to metric instruction, all participants completed attitude scales and metric knowledge tests. The same tests were administered at the end of fifteen hours of instruction.

Materials

A total of eight metric specialists taught the fifteen hours of metric instruction during the time period from September, 1977, through February, 1978. Each instructor followed an outline which was constructed by metric consultants. (Whittington and Chadick, 1977) Prior to instruction, each participant was given the metric attitude scale and knowledge test. These instruments were constructed by the chief metric consultant. (Whittington, 1977) Each participant received a copy of the outline and metric measuring devices. Instructors were provided with a complete set of measuring devices which were used in class demonstrations. All materials were geared for practical understanding and application by subjects. Special attention was given to the construction of teacher-made metric aids.

Procedure

This study was designed to survey the topic of cross-lagged panel analysis and to employ this technique in answering the questions proposed. Although the apparent simplicity of the cross-lagged panel analysis is deceiving, this quasi-experimental design makes possible the inference of causal relationships. Crano, Kenny, and Campbell (1972:258-275); Dyer and Miller (1974:49-51); Pelz and Andrews (1964:836-848); Atkin and others (1977:944-952), and Rozelle and Campbell (1969: 74-80) reported studies using the cross-lagged panel analysis to infer causal relationships. The method, basic assumptions, complexities, threats to internal validity, and application to the metric inservice results are presented.

Cross-lagged panel analysis is a quasi-experimental design which can be used to provide a hint of causality. Although neither manipulation of the independent variable nor randomization is possible, the researcher can control the time at which the independent variable is introduced. This type of analysis requires correlational information on two variables at more than one point in time. Lag refers to the period of time between measures. Correlation does not imply causation, but cross-lagged panel analysis has made the inference of causal relationships on the basis of correlational results possible. (Crano, Kenny, and Campbell, 1972: 260) Economic, political, demographic, and behavioral variables can be investigated using cross-lagged panel analysis. (Huck, Cormier, and Bounds, 1974:323) To the unintrusive observer, cross-lagged analysis is one of the three available designs found to be worth application and careful examination. The other designs are interrupted time-series design and multiple time-series design. (Campbell, 1963:242)

Cross-lagged panel analysis is based upon one of science's most useful rules of causal inference--that of time precedence. In every science, when a given event consistently precedes the occurrence of another and the reverse does not hold, one of only two possibilities is entertained: (1) Event A, initial attitude toward metrication, is presumed to be a cause, possibly one of many, of Event B, growth in metric knowledge, or (2) both Event A and Event B are the effects of some more general cause or causes. (Crano, Kenny, and

Campbell, 1972:261) Control of the application of the independent variable renders the second alternative implausible. The experimenter is assured that the occurrence of the independent variable was not dependent upon a more general previous event, and, thus, many differences occurring between experimental and control subjects can be attributed to the presence or absence of the independent variable. Hence, alternative two is rendered implausible. (Crano, Kenny, and Campbell, 1972:261)

Contrary to initial assumptions, cross-lagged panel analysis does not always result in an unambiguous decision between two competing hypotheses. Four hypotheses must be considered: (1) More favorable initial attitudes toward metrication enhance metric understanding, or less favorable initial attitudes hinder metric understanding. (2) More favorable initial attitudes toward metrication hinder metric understanding, or less favorable initial attitudes enhance metric understanding. (3) More comprehensive initial understanding enhances attitudes toward metrication, or less comprehensive understanding hinders attitudes toward metrication, and (4) More comprehensive initial understanding hinders attitudes toward metrication, or less comprehensive understanding enhances attitudes toward metrication.

Initially, only two hypotheses were in competition: (1) More favorable initial attitudes cause more comprehensive understanding, and (2) More comprehensive understanding causes more favorable attitudes. This assumption has been

recognized as a gross simplification of the process. The existence of "confounded hypotheses" has rendered the cross-lagged analysis effective only in allowing the investigator to choose between pairs of logical possibilities: (1) A increases B while B decreases A and (2) B increases A while A decreases B.

A and B represent the two variables of the sample--attitude measurement and understanding measurement. Both are subject to measurement error, and from time to time, A changes as a result of some force which is not attributable to B. Whenever A changes, the change at time t, denoted by 0 in this study, produces a related change (positive or negative) in B within a certain interval of causation, denoted by 15 which refers to the number of hours of metric instruction provided. B is also subject to the effects of other factors.

Certain minimum assumptions must be met for the cross-lagged panel analysis to work effectively. The basic assumptions quoted by Pelz and Andrews (1964:839) are stated in general terms. A_t represents A_0, A_{t+k} represents A_{0+15} where k is the interval of causation, B_t represents B_0, and B_{t+k} represents B_{0+15}.

1. Changes constantly occur in the state of variable A for each individual. If each person's A value became constant (A_tA_{t+k} approaching unity), then all cross-correlations [1, 2, 5, and 6 in Figure 1] would approach identity.

2. The causal effect of A on B is not immediate, but occurs over a certain interval. Suppose B changed simultaneously when A changed. Under our model, the correlation A_tB_t would equal 1.00. Assuming moderate consistency in A as before ($A_tA_{t+k} = .70$), it would then follow that both of the cross-lagged correlations [A_tB_{t+k} and B_tA_{t+k}] must equal .70. The two diagonals would be equal and less than the simultaneous correlations.

3. While we must assume that A is not completely consistent over time, it is also necessary to assume that A is not markedly inconsistent.

Insert Figure 1

These basic assumptions were used to interpret the results of the analyses of the metric data. The five aspects which should be present in a model for cross-lagged analysis as listed by Rozelle and Campbell (1969:77) are:

1. The causal symmetry should be similarly diagnosable by either lagged time-series or lagged panel correlations.
2. Replications of a set of cross-lagged panel correlation values at various time periods should show the same values. A specific implication is that within any one cross-lagged panel correlation, the two synchronous cross correlations [r] should be identical [$r_{A_0B_0} = r_{A_0 + 15B_0 + 15}$] except for sampling errors. This, of course, is not the effects of positive causal influence, or of steadily decreasing or increasingly negative ones in the case of negative causes. One needs multiple time periods to choose.
3. The correlation levels should show attenuation over time. For cross-sectional or panel correlations, the longer the lapsed time the lower the correlation, both for test-retest values of the same variables and for cross-correlations. Where one has specific causal mechanisms in mind which involve specified minimum lags of onset periods, one would want to modify the model appropriately for the causal cross-correlational effects involved, but not for the background of 'normal' relations against which causal effects are compared.
4. 'Third-variable' and 'co-symptom' effects over and beyond any mutual causal relations are assumed.
5. Only the slowed-up causal sequences can be diagnosed by the cross-lagged panel correlation.

Application of the cross-lagged panel analysis technique using the four measurements--intial attitude (A_0), initial metric understanding (B_0), final attitude ($A_{0 + 15}$), and final

understanding ($B_{0 + 15}$)--yields six correlation coefficients. The following figure presents the six correlations among the two variables measured twice.

Insert Figure 2

The vertical correlations, $r_{A_0B_0}$ and $r_{A_{0 + 15}B_{0 + 15}}$, are called unlagged synchronous correlations. The horizontal correlations, $r_{A_0A_{0 + 15}}$ and $r_{B_0B_{0 + 15}}$, are called lagged autocorrelations; coefficients $r_{A_0B_{0 + 15}}$ and $r_{B_0A_{0 + 15}}$ are the cross-lagged correlation coefficients. The correlation for the two panels of one variable reflects consistency in each variable over time and reveals test-retest reliability. (Huck, Cormier, and Bounds, 1974:325) The correlations which are cross-lagged over time provide information regarding the direction of the causal relationship. (Dyer and Miller, 1974: 49)

Cross-lagged panel analysis must rely on statistical treatment, rather than direct manipulation. Coefficients $r_{A_0B_0}$ and $r_{A_{0 + 15}B_{0 + 15}}$ are statistically compared to determine if a significant difference exists. The same procedure is applied to $r_{A_0A_{0 + 15}}$ and $r_{B_0B_{0 + 15}}$ and $r_{A_0B_{0 + 15}}$ and $r_{B_0A_{0 + 15}}$. The following z-test formula was used in determining whether the pairs of coefficients were significantly different.

$$z = \frac{\sqrt{N - 1}\left[(r_{12} - r_{34}) - (\rho_{12} - \rho_{34})\right]}{\hat{\sigma}_{r_{12} - r_{34}}}$$

where

$$\hat{\sigma}^2_{r_{12} - r_{34}} = (1 - r_{12}^2)^2 + (1 - r_{34}^2)^2 + r_{12}r_{34}\left[r_{13}^2 + r_{14}^2 + r_{23}^2 + r_{24}^2\right] + 2\left[r_{13}r_{24} + r_{14}r_{23}\right] - 2\left[r_{12}r_{13}r_{14} + r_{12}r_{23}r_{24} + r_{13}r_{23}r_{34} + r_{14}r_{24}r_{34}\right].$$

(Yee, 1965)

The correlation between A_0 and B_{0+15} should be significantly different from the correlation between B_0 and B_{0+15} if the causal relationship exists. The larger coefficient indicates the direction of the causal relationship. The opposite diagonal correlation should be relatively small. "A clear difference between the two diagonals should appear." (Pelz and Andrews, 1964:838) Additionally, "intuition also suggests that the cross-lagged correlation 5 (A_tB_{t+k}) should be larger than either simultaneous unlagged correlation 1 or 2 (A_tB_t or $A_{t+k}B_{t+k}$), if k is close to the causal interval." (Pelz and Andrews, 1964:838) (See Figure 1) Thus, using the cross-lagged correlation coefficients in relationship to the other four coefficients, the experimenter can infer possible causal influence or source of change. (Huck, Cormier, and Bounds, 1974:325)

Causation is not always simple to infer using the cross-lagged panel analysis. The inequality $r_{A_tB_{t+k}}$ is greater than $r_{B_tA_{t+k}}$ can possibly involve the following combination of effects:

The joint effect of A increases B and B decreases A	>	The joint effect of B increases A and A decreases B

These joint effects are referred to as confounded hypotheses. In some cases, as in the situation under investigation, only two of the four have any creditability. (Rozelle and Campbell, 1969:75) But, according to Crano, Kenny, and Campbell (1972: 262), "in many other investigative situations amenable to the cross-lagged panel analysis, the degree of existing knowledge regarding the general relationship between the two variables of interest is so restricted that none of the four competing hypotheses can arbitrarily be discarded."

In such cases, cross-lagged panel analysis may not inable the researcher to make unambiguous decisions about the competing hypotheses. The apparent simplicity of the method is deceptive. Two important possibilities which should be considered are that other variables may contribute more to the causal relationship than the variables under consideration and that the relative stability of a measure may increase in reliability from the first panel to the second panel. As a result, that variable may show up as the effect when it is, in fact, the cause. (Huck, Cormier, and Bounds, 1974:325)

To help rule out reliability shifts, the cross-lagged panel correlations should be corrected for attenuation when the reliability decreases over time. Longer lag between panels for time-series lowers the correlation coefficient for auto-correlations and cross-correlations, and the effects of a causal state or event decrease over time. To correct and eliminate rival hypotheses, the experimenter should add a third panel to the cross-lagged panel design, a consideration

which was not possible in the present study. The addition of the third panel will aid in determining whether the causal relationship is unidirectional or bidirectional. (Huck, Cormier, and Bounds, 1974:325) Dyer and Miller (1974:50) used a three-panel cross-lagged analysis to study the relationship between intelligence and achievement, measured during Head Start, kindergarten, and first grade.

RESULTS

The correlation matrix among the four measurements from the "Going Metric" project is presented in Table 1. The same information is diagrammed in Figure 2, along with the means of the four measurements. The negative relationships were determined to be highly improbable. In fact, not one of the coefficients was negative. The remaining hypotheses to be considered were: (1) More favorable initial attitudes toward metrication enhance metric understanding, or less favorable initial attitudes hinder metric understanding. (2) More comprehensive initial understanding enhances attitudes toward metrication, or less comprehensive understanding hinders attitudes toward metrication.

Although the cross-lagged correlations were of primary interest, all six correlations were significant at $p < .01$, $df = 265$. The lagged correlations, $r_{A_0A_{0+15}} = .5783$ ($t = 11.539303$) and $r_{B_0B_{0+15}} = .2502$ ($t = 4.2067602$), were not as great as is desired for test-retest reliability; but an examination of the means shows a great improvement in both attitude

and understanding. The mean understanding score doubled while the attitude score improved by approximately ten points.

The unlagged synchronous coefficients were $r_{A_0B_0}$ = .3138 (t = 5.3800475) and $r_{A_{0+15}B_{0+15}}$ = .3024 (t = 5.1645117). Rozelle and Campbell (1969:77) said that the two synchronous cross-correlations should be identical to insure that replications of the set of cross-lagged panel correlation values at various time periods is possible.

The cross-lagged correlations, $r_{A_0B_{0+15}}$ = .2783 (t = 5.3800445) and $r_{B_0A_{0+15}}$ (t = 2.9361135), were not significantly different (z = 1.1416). Therefore the hypotheses that initial attitudes influence final knowledge or that initial knowledge influences attitudes cannot be untangled. The results do tend to indicate that initial attitudes influence final knowledge, but this hypothesis cannot be substantiated.

DISCUSSION

The absence of a significant difference between the two cross-lagged correlations can be attributed to the extended time lapse between the measurements, ranging from late August to mid-February. Rozelle and Campbell (1969:77) said that the longer the lapsed time the lower the correlations would be. The fact that all measurements increased considerably is another possible explanation.

At this point, the all-important threats to the internal validity are of interest. Threats related to history, maturation, testing, and mortality are not controlled due to the lack

of randomization, manipulation of the independent variable, and assignment of subjects to the comparison groups. The same subjects are measured in all four instances. A third variable or event occurring between the first and second measurements may influence their relationship or provide a plausible explanation of the relationship under consideration. The time lag allows for the threat of maturation as a rival explanation. Mortality or dropouts between the panels is a possible explanation for the relationship between the variables.

The threat of selection is not present in the cross-lagged panel analysis. If subjects are selected on the basis of extreme scores or dichotomous data, statistical regression is possible and may be reflected in the coefficients between the lagged and unlagged variables. Instrumentation is not a problem if the same procedures and instruments or alternate forms are used for both panels of measurement and if the reliability of the instrument or procedure is high. (Huck, Cormier, and Bounds, 1974:325)

Because of the threats to validity and the existence of "confounded hypotheses," cross-lagged analysis has been determined to be much less powerful than in initial estimates, even though the confounded pair of hypotheses can be separately examined under some conditions. (Lieberman, 1971:412) The cross-lagged procedure provides a realistic choice among the possibilities. Actions taken on the basis of the results obtained in an investigation will vary according to prior

theoretical commitments of the experimenter, but these actions will, at least, be partially grounded in or constrained by empirical evidence by way of cross-lagged analysis.

A word of caution regarding the generalization of this analytic method to other causal questions is in order because the apparent simplicity of the method is deceiving. Although the correlations tend to support the hypothesis that initial attitude affects final understanding more than initial understanding affects final attitude, a clear conclusion is not possible. The important fact to remember is that the subjects improved attitudes and understanding substantially and are, without doubt, more adequately prepared to teach metric measurement.

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Appendix A

Basic Metric Outline
"Think Metric" Approach

I. Readiness
   A. Importance of going metric
   B. Relevance of metric units

II. Linear measure
   A. Basic unit and symbol
   B. Multiples and divisions and symbols
   C. Activities
      1. Estimation
      2. Measurement
      3. Internal conversions

III. Area
   A. Basic unit and symbol
   B. Multiples and divisions and symbols
   C. Activities
      1. Estimation
      2. Measurement
      3. Internal conversions

IV. Volume
   A. Basic unit and symbol
   B. Multiples and divisions and symbols
   C. Activities
      1. Estimation
      2. Measurement
      3. Internal conversions

V. Capacity
   A. Basic unit and symbol
   B. Multiples and divisions and symbols
   C. Activities
      1. Estimation
      2. Measurement
      3. Internal conversions

VI. Weight
   A. Basic unit and symbol
   B. Multiples and divisions and symbols
   C. Activities
      1. Estimation
      2. Measurement
      3. Internal conversions

VII. Temperature
- A. Basic Unit
- B. Important ranges
- C. Activities
  1. Estimation
  2. Measurement

Figure 1

Six Correlations Among Two Variables
Measured Twice

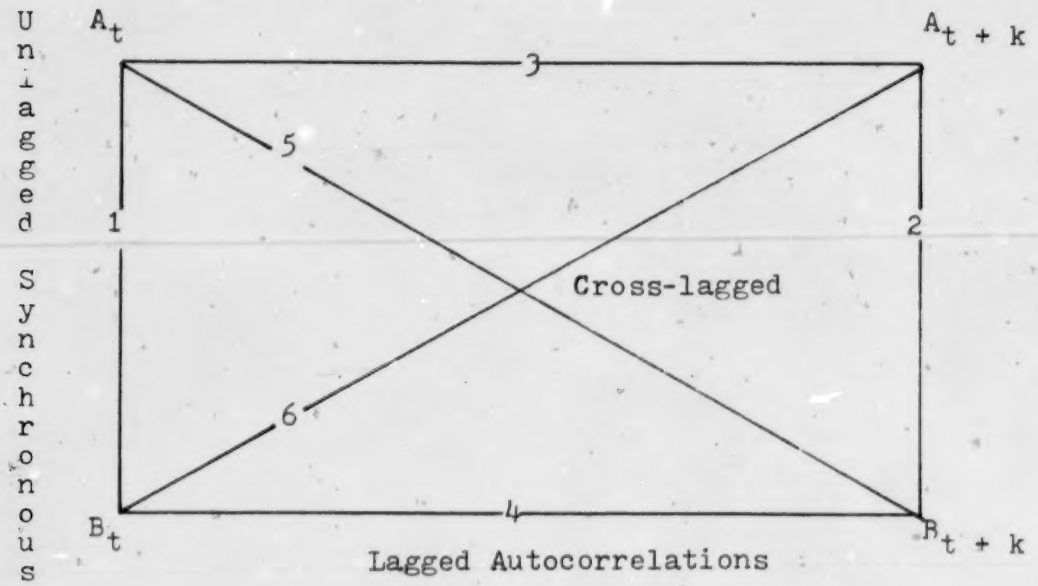

Figure 2

Data From "Going Metric" Project
Attitude and Understanding

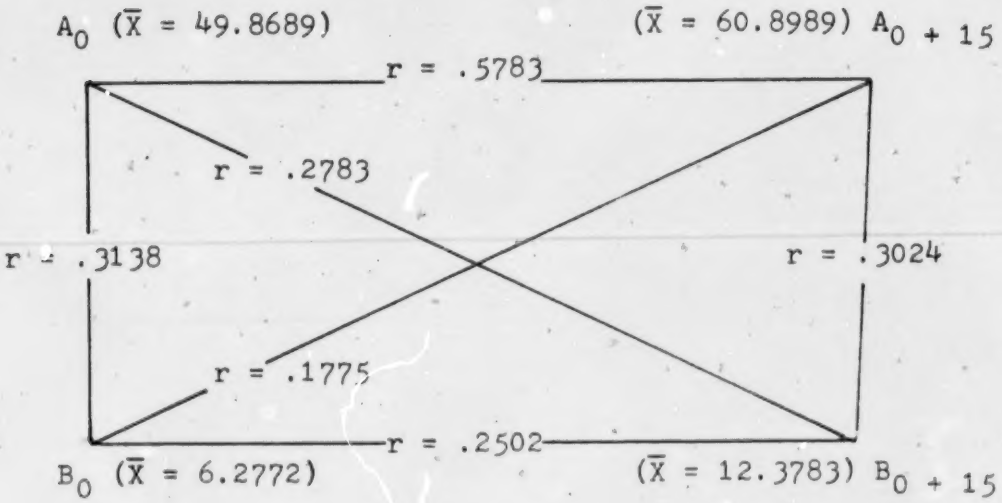

Table 1

Matrix of Correlation Coefficients
Attitude and Understanding

		1	2	3	4
1.	Initial Attitude (A_0)	1	.2783	.5783	.3138
2.	Final Understanding (B_{0+15})	-	1	.3024	.2502
3.	Final Attitude (A_{0+15})	-	-	1	.1775
4.	Initial Understanding (B_0)	-	-	-	1